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JAPAN PATENT OFFICE

This is to certify that the annexed is a true copy of the following application as filed with this Office.

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[Title of Invention] OPTICAL DISC MEDIUM AND OPTICAL DISC APPARATUS

[Claim for Patent]

[Claim 1] A disc-shaped optical disc medium provided with a spiral-shaped recording track, said optical disc medium being divided in a radial direction to form a data recording area and a system information recording area, said data recording area having a shortest pit length L1 of data to be recorded or reproduced that satisfies the relationship $L1 < 0.35 \times \lambda/NA$ represented by the use of a light source wavelength $\lambda$ for use in recording and reproducing and a numerical aperture NA of an object lens, said data recording area having a PRSNR value defined as a quality evaluation index in PRML that is not less than 14, the system information recording area having a shortest pit length L2 of data to be reproduced only that satisfies the relationship $L2 > 0.50 \times \lambda/NA$, the system information recording area having a track pitch wider than that of the data recording area.

[Claim 2] The optical disc medium as claimed in claim 1, wherein the system information recording area is formed on an inner peripheral side of the data recording area.

[Claim 3] The optical disc medium as claimed in claim 1, wherein the shortest pit length of the system information recording area corresponds approximately to an integral multiple of that of the data recording area.

[Claim 4] The optical disc medium as claimed in claim 1, the system information recording area having a specific recoding density and arranged at a particular radial position, wherein the data recording area is one of three types, i.e., a reproducible-only type, an additionally recordable type, and a rewritable type, the system information recording area recording information indicating one of the three types therein.

[Claim 5] An optical disc apparatus for recording or reproducing data in an optical disc medium having two recording areas, the optical disc medium being divided in a radial direction to form a data recording area and a system information recording area, the data recording area having a shortest pit length L1 of data to be recorded or reproduced or data to be reproduced only that satisfies the relationship $L1 < 0.35 \times \lambda/NA$ represented by the use of a light source wavelength λ for use in recording and reproducing and a numerical aperture NA of an object lens, said data recording area having a PRSNR value defined as a quality evaluation index in PRML that is not less than 14, the system information recording area having a shortest pit length L2 of data to be reproduced only that satisfies the relationship $L2 > 0.50 \times \lambda/NA$, wherein:

recorded data are reproduced by binary equalization in the system information recording area; and

recorded data are reproduced by partial-response equalization in the data recording area.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to an optical disc medium for use in recording and reproducing of information using an optical minute spot and an optical disc apparatus for recording and reproducing therefor.

[0002]

[Prior Art]

In optical recording, recording or reproducing of information is carried out by using an object lens to form a minute spot on a disc recording surface. A recording/reproducing characteristic is determined by a size of the minute spot and a length of a recording pit formed on the recording surface.

[0003]

It is known that the size of the spot is proportional to a wavelength $\lambda$ of an optical source and is inversely proportional to a numerical aperture NA of the object lens. When recording pits formed on the optical disc are reduced in cycle, the amplitude of a reproduced signal obtained as variation of a reflected light beam from the object lens is gradually narrowed. At 0.5 x $\lambda$/NA, the signal is cut off and the amplitude becomes equal to zero.

[0004]

Fig. 7 is a view showing a relationship between a pit cycle in the optical disc and the amplitude of the reproduced signal

[0005]

In most of recording methods of the optical disc in which front edges or rear edges of pits correspond to transition points between 1 and 0 of a train of encoded data, a shortest pit length is equal to a shortest length between the pits. As a result, the pit length is equal to a half of the pit cycle shown in Fig. 7. In this event, the pit length of cut-off is equal to 0.25 x $\lambda$/NA.

[0006]

In optical discs, such as CD and DVD, which have been widely used, reproduction of data is carried out by binary equalizing a reproduced signal and determining presence or absence of the pits using a suitable slice. Accordingly, unless the reproduced signal at a shortest pit has some degree of amplitude, it is impossible to ensure sufficient reliability of reproduced data.

[0007]

Fig. 8 shows an example of measurement of the shortest pit length and an error rate of the reproduced signal. A broken line in the Fig. 8 shows a conventional example where data reproduction is carried out by binary equalization. It is understood that the error rate is drastically degraded when the pit length is less than 0.35$\lambda$/NA. A dot-dash-line shows a standard error rate which is practically allowable. Thus, a limit of a practical shortest pit length

in the conventional binary equalization is about 0.35λ/NA. For example, about 0.37λ/NA is used in the DVD.

[0008]

In recent years, as a technique aimed at further increase in recording density of the optical disc, a reproduced signal detection method called PRML (Partial-Response Maximum-Likelihood) has started to be introduced. This technique is characterized by performing equalization of the reproduced signal into to a multi-value signal, called partial-response equalization, without equalizing the reproduced signal into a simple binary signal. For example, Fig. 9 shows an example of a waveform of the reproduced signal in case of waveform equalization into a partial-response class called PR (1, 2, 2, 2, 1). In this class, the reproduced signal is equalized into nine-value levels shown by arrows labeled multi-value equalization level 5 in the figure. Further, in accordance with regularity of temporal transition between the multi-value levels, the signal is demodulated into a data signal sequence of maximum likelihood by Viterbi decoding. Thus, it is possible to obtain a sufficiently practical reproduction characteristic even in an area where the amplitude of the reproduced signal from the shortest pit is small. A solid line in Fig. 8 shows an example of measurement of a reproduction error rate in case where the PRML is used. It is understood that a good characteristic is obtained to a short pit length as compared with the conventional technique.

[0009]

[Problem to be Solved by the Invention]

In case where the PRML is used, it is necessary to precisely control an amplitude value of the reproduced signal and a characteristic of a filter used in equalization because the reproduced signal is equalized not into a simple binary signal but into a multi-value signal.

[0010]

In optical disc media, it is often that various kinds of information related to recorded data is recorded in a particular area, called a system information recording area, which is separate from an ordinary data recording area. If an amplitude characteristic of the recorded data and so on are recorded as such information, it is possible to stably reproduce the recorded data, upon reproduction by the optical disc apparatus, by setting a circuit according to the information.

[0011]

However, in a format of the existing optical disc medium, the information is recorded in the system information recording area under a recording density condition which is substantially same as the recording density in the data recording area. Therefore, in order to read the information from the system information recording area, precise setting of operational parameters for a PRML circuit is required from the start. Therefore, a certain extent of trial and error for setting values is unavoidable in order to realize stable signal reproduction.

[0012]

It is therefore a technical object of the present invention to provide an optical disc medium and an optical disc apparatus which are capable of realizing stable recording/reproducing without causing the above-mentioned problem.

[0013]

[Means to Solve the Problem]

According to this invention, there is provided a disc-shaped optical disc medium provided with a spiral-shaped recording track, characterized in that said optical disc medium is divided in a radial direction to form a data recording area and a system information recording area, said data recording area having a shortest pit length L1 of data to be recorded or reproduced that satisfies the

relationship L1 < 0.35 x λ/NA represented by the use of a light source wavelength λ for use in recording and reproducing and a numerical aperture NA of an object lens, said data recording area having a PRSNR value defined as a quality evaluation index in PRML that is not less than 14, the system information recording area having a shortest pit length L2 of data to be reproduced only that satisfies the relationship L2 > 0.50 x λ/NA, the system information recording area having a track pitch wider than that of the data recording area.

[0014]

According to this invention, the optical disc medium is characterized in that the system information recording area is formed on an inner peripheral side of the data recording area.

[0015]

According to this invention, the optical disc medium is characterized in that the shortest pit length of the system information recording area corresponds approximately to an integral multiple of that of the data recording area.

[0016]

According to this invention, the optical disc medium in which the system information recording area having a specific recoding density and arranged at a particular radial position, is characterized in that the data recording area is one of three types, i.e., a reproducible-only type, an additionally recordable type, and a rewritable type, the system information recording area recording information indicating one of the three types therein.

[0017]

According to this invention, there is provided an optical disc apparatus for recording or reproducing data in an optical disc medium having two recording areas, the optical disc medium being divided in a radial direction to form a data recording area and a system information recording area, the data

recording area having a shortest pit length L1 of data to be recorded or reproduced or data to be reproduced only that satisfies the relationship $L1 < 0.35 \times \lambda/NA$ represented by the use of a light source wavelength $\lambda$ for use in recording and reproducing and a numerical aperture NA of an object lens, said data recording area having a PRSNR value defined as a quality evaluation index in PRML that is not less than 14, the system information recording area having a shortest pit length L2 of data to be reproduced only that satisfies the relationship $L2 > 0.50 \times \lambda/NA$, characterized in that recorded data are reproduced by binary equalization in the system information recording area and that recorded data are reproduced by partial-response equalization in the data recording area.

[0018]

[Mode of Embodying the Invention]

Now, an embodiment of the present invention will be described with reference to the drawing.

[0019]

Fig. 1 is a view schematically showing an optical disc according to an embodiment of the present invention. Referring to Fig. 1, the optical disc 1 is provided with a spiral-shaped recording track 4. A recording surface is divided into a data recording area 2 and a system information recording area 3 by a radial position.

[0020]

In case of an optical disc medium of a reproducible-only type, data recording in the data recording area 2 is carried out by a train of embossed pits. On the other hand, in case of an optical disc medium of an additionally recordable or a rewritable type, a recording firm is formed on a track having a groove structure or on a track having both of land and groove structures to serve as an area where recording data are written by an optical disc apparatus.

[0021]

On the other hand, the system information recording area 3 serves as a reproducible-only area for a typical optical disc apparatus. Accordingly, data recording by the train of the embossed pits is possible irrespective of the reproducible-only type, the additionally recordable type, or the rewritable type. In the optical disc medium of the additionally recordable or the rewritable type, the recording firm is formed on this area also. However, there is no problem if reproduction from the embossed pits can be carried out. Furthermore, the system information recoding area may be formed by writing system data in the recording film on a manufacturing side of the optical disc medium without forming the embossed pits.

[0022]

In the system information recording area, a recording density of the data recording area, an optimal reproduction condition, and the like may be recorded as information of the optical disc medium. The system information recording area may be formed at any position on the optical disc as far as the optical disc is divided in a radial direction. However, it is desirable that the system information recording area is formed on an inner peripheral side of the optical disc because surface wobbling is relatively small and servo pull-in operation is easy. In addition, in all kinds of optical disc media regardless of the reproducible-only type, the additionally recordable type, and the rewritable type, it is preferable that the system information recording area is formed at the same radial position and the type of the medium is recorded therein. In this case, it is advantageously possible to shorten a time period required for the optical disc apparatus to determine the type of the optical disc medium and to start recording or reproducing operation.

[0023]

In order to realize large-capacity and high-density recording, the data

recording area has a shortest recording pit length which is not more than 0.35 x $\lambda$/NA on the assumption that reproduction is carried out by the PRML method. For example, it is assumed that a wavelength $\lambda$ of a light source is 405nm and a numerical aperture NA of an object lens is 0.65. In this event, it is possible to realize data recording at the shortest pit length of about 0.2µm. It is assumed that recording encoding is carried out by the use of (1, 7) code which has a wide detection window margin and which is suitable for high-density recording. In this event, one bit data are converted into a recording channel bit of 1.5 bits. The shortest pit length on the recording track is equal to two channel bit length. Under this condition, when the track pitch is set to about 0.34-0.40µm, it is possible to realize a data recording capacity of 15-20 GB on one side of the optical disc medium of 12cm.

[0024]

Fig. 2 is a view showing an example of a reproduced signal of the data recording area according to the (1, 7) coding. Referring to Fig. 2, a signal amplitude by repetition of the shortest recording pits is as considerably small as less than 10% as compared with that of a signal by long recording pits. Accordingly, it is difficult to ensure sufficient reliability of the reproduced data only by simple binary equalization. It is possible to carry out data reproduction of high reliability by equalizing the reproduce signal into a multi-value signal shown in Fig. 9 and by reproducing using Viterbi decoding.

[0025]

However, a good reproduction characteristic cannot be obtained if the shortest recording pit length is excessively short. Accordingly, the quality of the data recording area is guaranteed by defining the signal quality of the PRML by an index as follows.

[0026]

In the PRML, discrimination of data is carried out in accordance with

an algorithm called Viterbi decoding. In the Viterbi decoding, in every clock cycle, a square of a difference between the value of a reproduced signal and a predetermined equalization level defined by partial response equalization is calculated. Along each path, the square sum is obtained. One of the paths which provides the smallest square sum is selected. Thus, decoding of the data is carried out.

[0027]

When the Euclid distance between the paths is small, a detection error tends to occur in the Viterbi decoding. Assuming that $B(D) = \Sigma b_k D^k$ denotes a polynomial defined by a data string $b_k$ along one of the paths, $C(D) = \Sigma c_k D^k$ denotes a polynomial defined by a data string $c_k$ along the other path ($b_k$ and $c_k$ are binary data of 1 or -1), and $H(D) = \Sigma h_k D^k$ is a polynomial defining partial response equalization and from $N(D) = (B(D) - C(D))H(D) = 2\Sigma\varepsilon_i D^i$, the Euclid distance d between the different paths is defined by $d^2 = 4\Sigma\varepsilon_i^2$, where D represents a time delay operator using a clock time as a unit, and $h_k$ represents a predetermined partial response equalization characteristic. The partial response equalization characteristic is generally represented as $PR(h_0, h_1, h_2, h_3, \ldots)$ by using elements of $h_k$ which are not equal to 0.

[0028]

It is assumed that the partial response is defined as $h_0 = 1$, $h_1 = 2$, $h_2 = 1$, and $h_3$ and subsequent values are all equal to 0 (in this case, represented as PR(1,2,1)), that the data string $b_k$ is defined as $b_0 = 1$, $b_1 = 1$, $b_2 = -1$, $b_3$ and subsequent data are all equal to -1, and that the data string $c_k$ is defined as $c_0 = -1$, $c_1 = 1$, $c_2 = 1$, and $c_3$ and subsequent data are all equal to -1. In this case, from $N(D) = 2(1 - D^2)(1 + 2D + D^2) = 2 \times (1 + 2D - 2D^3 - D^4)$, the Euclid distance between the path along the data string $b_k$ and the path along the data string $c_k$ is obtained as $d^2 = 4 \times (1 \times 1 + 2 \times 2 + 2 \times 2 + 1 \times 1)$ (although a combination of 1 and 0 or a combination of 1 and -1 may be used to express binary data, the

combination of 1 and -1 is used in the instant specification).

[0029]

When the polynomial of the partial response equalization is defined, the Euclid distance between the paths can be calculated for each set of $\varepsilon_i$. For an optical disc, a recording symbol $d \geq 1$ is generally used to limit the run length. For example, when the recording symbol of $d = 1$ is used, a mark having a length equal to or greater than 2T is recorded on the disc. In order to take this limitation into account in the calculation of the Euclid distance, restriction given by $\varepsilon_i\varepsilon_{i+1} \neq -1$ must be imposed for the set of $\varepsilon_i$. That is, as the data strings satisfying $\varepsilon_i\varepsilon_{i+1} = -1$, (x, 1, -1, y) may be used as the data string $b_k$ and (x, -1, 1, y) may be used as the data string $c_k$. However, the pattern (1, -1, 1) or (-1, 1, -1) is prohibited under the limitation of d = 1. Therefore, in case where x = -1 or y = 1, the data string $b_k$ becomes a pattern that breaks the run length limitation (a pattern that can not exist). In case where x = 1 or y = -1, the data string $c_k$ is a pattern that breaks the run length limitation. Therefore, a combination of the data strings $b_k$ and $c_k$ does not exist that satisfies $\varepsilon_i\varepsilon_{i+1} = -1$ while the run length limitation is satisfied. When the length of a mark recorded on the disc is equal to or greater than 3T, the restriction represented by $\varepsilon_i\varepsilon_{i+1} \neq -1$ and $\varepsilon_i\varepsilon_{i+2} \neq -1$ is imposed.

[0030]

With respect to the data string $b_k$ for example, the probability of occurrence of a detection error between the two paths with the Euclid distance d is equivalent to the probability at which $\Sigma(y_k - \Sigma b_{k-i}h_i)^2$ is greater than $\Sigma(y_k - \Sigma c_{k-i}h_i)^2$ under influence of noise. With respect to the data string $b_k$, $y_k - \Sigma b_{k-i}h_i$ is an equalization error. Further, the relationship in magnitude between $\Sigma(y_k - \Sigma b_{k-i}h_i)^2$ and $\Sigma(y_k - \Sigma c_{k-i}h_i)^2$ may be observed as follows. An error vector is defined by regarding, as vector elements, coefficients of the polynomial defined by the difference between B(D)H(D) and C(D)H(D). On the error vector, the

equalization error is projected. In this case, the probability of occurrence of a detection error is defined as the probability at which the magnitude of the noise (the variance of the noise) projected onto the error vector is greater than a half the Euclid distance between the paths. Therefore, by calculating the ratio of the Euclid distance between the paths and the variance of the noise projected onto the error vector, it is possible to estimate the signal quality. When data are obtained in advance, for example, upon adjusting the recording condition, this data string may be used as a reference data string. When data have not been obtained, binary data obtained by a Viterbi decoder as likelihood data may be used.

[0031]

It is assumed that the data string $b_k$ is defined as $b_0 = -1$, $b_1 = 1$, and $b_2$ and subsequent data are all equal to 1 and that the data string $c_k$ is defined as $c_0 = 1$ and $c_1$ and subsequent data are all equal to 1. Then, $\alpha_0 = 0$ and $\alpha_1$ and subsequent values are all equal to 0 in $A(D) = C(D) - B(D) = 2\Sigma\alpha_j D^j$. For example, when $h_0 = 1$, $h_1 = 2$, $h_2 = 2$ and $h_3 = 1$ are used as $H(D)$ (corresponding to PR(1,2,2,1)), the coefficients $\varepsilon_i$ of the polynomial $N(D) = A(D)H(D) = 2\Sigma\varepsilon_i D^i$, which defines the error vector are (1,2,2,1) in the order of $\varepsilon_0$, $\varepsilon_1$, $\varepsilon_2$ and $\varepsilon_3$. Therefore, the probability at which the data string $b_k$ is erroneously regarded as the data string $c_k$ for PR(1,2,2,1) is equal to the probability at which the magnitude of the equalization error projected onto 2 x (1,2,2,1) is greater than a half of the Euclid distance (in this case, $2 \times (1 + 2 \times 2 + 2 \times 2 + 1)^{1/2}$) between the two paths. The projection of the equalization error onto the error vector is represented by the following equation 1. Therefore, the variance CN of the noise projected onto the error vector is represented by the following equation 2.

[0032]

[Equation 1]

$$\frac{2\sum_{i}\varepsilon_i v_{k+i}}{2\sqrt{\sum_{i}\varepsilon_i^2}}$$

[Equation 2]

$$CN = \frac{\sum_{k=1}^{N}\left(\sum_{i}\varepsilon_i v_{k+i}\right)^2}{N\sum_{i}\varepsilon_i^2}$$

[0033]

A half of the Euclid distance between the two paths, which corresponds to the signal amplitude, is represented by the following equation 3. The square E of the amplitude that corresponds to electric power is represented by the following equation 4. E/CN is obtained as an index that is correlated with the error probability.

[0034]

[Equation 3]

$$\sqrt{\sum_{i}\varepsilon_i^2}$$

[Equation 4]

$$E = \sum_{i}\varepsilon_i^2$$

[0035]

(The coefficient 2 related to the entire A(D) and N(D) does not affect the calculation result. Therefore, the same result is obtained through the calculation using $A(D) = \Sigma\alpha_j D^j$ and $N(D) = \Sigma\varepsilon_i D^i$, with the coefficient 2 omitted.)

[0036]

As described above, it is assumed that the equalization error is given by $v_k = (y_k - \Sigma a_{k-i}h_i)$ for the value $y_k$ of a reproduced signal in each clock cycle, a

predetermined data string $a_k$ for generation of a target signal, and a predetermined partial response characteristic $h_k$, that D represents a time delay operator using a clock time as a unit, that $A(D) = \Sigma\alpha_j D^j$ is a polynomial defined by using a coefficient $\alpha_j$ having a value of one of 1, 0 or -1 and satisfying $\alpha_j\alpha_{j+1} \neq -1$, and that $H(D) = \Sigma h_k D_k$ is a polynomial that defines a partial response. According to the polynomial defined by $N(D) = A(D)H(D) = \Sigma\varepsilon_i D^i$, the signal quality evaluation index value defined by the following equation 5 is calculated. Then, it is possible to evaluate the probability of occurrence of a detection error, i.e., the signal quality of a reproduced signal.

[0037]

[Equation 5]

$$\mathrm{PRSNR} = \frac{N\left(\sum_i \varepsilon_i^2\right)^2}{\sum_{k=1}^{N}\left(\sum_i \varepsilon_i v_{k+i}\right)^2}$$

[0038]

Hereinafter, description will be made of examples of the PRSNR value measured by random data modulated according to the (1-7) modulation method which is effective in an increase in density. By the use of an optical head with a wavelength of 405 nm and an object lens having a numerical aperture (NA) of 0.65, the values under various recording density conditions were measured.

[0039]

The reproduced waveform was equalized to PR(1,2,2,2,1) and a bit error rate (bER) and the PRSNR were measured. The bER was measured by comparing the original data recorded on the optical disc with the binary data obtained through Viterbi decoding. The PRSNR was calculated by the use of $10^5$ values of reproduced waveform after partial response equalization obtained

in every clock cycle and the binary data obtained by Viterbi decoding.

[0040]

The (1-7) modulation codes have a limitation of $d \geq 1$. For PR(1,2,2,2,1), the Euclid distance is reduced with respect to $\varepsilon_j$ shown in Table 1 below. A set (1 2 2 2 1) of $\varepsilon_j$ discriminated by a pattern 1 in Table 1 is an error vector that is determined by two data strings that tend to be erroneously discriminated in Viterbi detection, e.g., $b_k$: (1 1 1 1 -1 -1 . . .) and $c_k$: (-1 1 1 1 -1 -1 . . .), and partial response equalization characteristic (1 2 2 2 1). For the sets of $\varepsilon_i$ in a pattern 2 and subsequent patterns in Table 1, the number of 0s inserted between (1, 2, 1) and (-1, -2, -1) and the upper limit number of 0s inserted between (1, 2, 1) and (1, 2, 1) are determined by the upper limit of the number of times of consecutive occurrence of mark/space for 2T (the upper limit of the number of times of consecutive occurrence of a data string +1 +1 -1 -1: counted as one time in case of -1 -1 -1 +1 +1 -1 -1 -1 and counted as two times in case of -1 -1 -1 +1 +1 -1 -1 +1 +1 +1). That is, when the upper limit of the number of times of consecutive occurrence of mark/space for 2T is 2n + 1, (4n + 1) of 0s are inserted between (1, 2, 1) and (-1, -2, -1) at maximum. When the upper limit of the number of times of consecutive occurrence is 2n + 2, (4n + 3) of 0s are inserted between (1, 2, 1) and (1, 2, 1) at maximum. Therefore, the PRSNR value is calculated taking into account the patterns up to the upper limit. In the following Table 1, examples of $\varepsilon_i$ are shown in case where the number of consecutive occurrence of 2T is up to five at maximum.

[0041]

Those patterns opposite in polarity to the patterns shown in Table 1 (for example, (-1 -2 -2 -2 -1) with respect to the pattern 1) may be used. However, since the same PRSNR value is obtained, consideration of patterns of a predetermined polarity (either polarity may be selected but the patterns of the both polarities need not be evaluated) is sufficient.

[0042]

[Table 1]

Examples of sets of $\varepsilon_i$

| PATTERN j | $\varepsilon_i$ | $\sum \varepsilon_i^2$ |
|---|---|---|
| 1 | 12221 | 14 |
| 2 | 1210-1-2-1 | 12 |
| 3 | 121000121 | 12 |
| 4 | 12100000-1-2-1 | 12 |
| 5 | 1210000000121 | 12 |
| 6 | 121000000000-1-2-1 | 12 |

[0043]

Fig. 3 shows the relationship between the measured PRSNR value and bER. Since bER allowed in an actual optical disc system is about $1 \times 10^{-4}$, the PRSNR value is required to be 14 or more.

[0044]

On the other hand, it is necessary for the system information recording area to realize reproduction by simple binary equalization which does not require so precise individual setting on the side of the optical disc apparatus. Accordingly, it is necessary to sufficiently reduce the recording density. Generally, the shortest recording pit length falling within a range between $0.4 \times \lambda/NA$ and $0.5 \times \lambda/NA$ is sufficient because the signal amplitude by repetition of short recording pits ensures about 30% or more of the signal amplitude by long recording pits.

[0045]

However, this density condition gives rise to a problem if stable data reproduction by binary equalization is carried out not only in the reproducible-only type but also in the additionally recordable type or the rewritable type.

[0046]

In case of the optical disc medium of the reproducible-only type, it is

possible to use embossed pits having a phase depth of about 1/4 wavelength like in the data recording area. Accordingly, as shown in Fig. 4(a), it is possible also in the system information recording area to obtain a sufficiently large signal amplitude with respect to a maximum DC level. On the other hand, in the optical disc medium of the additionally recordable type, a groove structure formed in the data recording area has a shallow groove having a phase depth of about 1/8 wavelength in order to obtain sensitivity of a track error signal according to a push-pull method. If embossed pits in the system information recording area are formed with the same phase depth, the sufficient signal amplitude can not be obtained with respect to the maximum DC level as shown in Fig. 4(b). Under the influence of variation in DC level or the like, sufficient reliability of data reproduction may not be obtained.

[0047]

In view of the above, in the present invention, consideration has been made about a condition under which a sufficient reproduced signal characteristic is obtained even with such shallow embossed pits. As a result, it has been confirmed that a stable characteristic is obtained when the shortest pit length is 0.50 x $\lambda$/NA or more. In this case, as shown in Fig. 5, it is possible to always assure that the signal amplitude by repetition of short recording pits is 50% or more of that by long recording pits.

[0048]

In order to further stabilize tracking servo operation required for signal reproduction, the system information recording area has a track pitch wider than that of the data recording area. For example, when the data recording area has the track pitch of 0.4μm, the system information recording area has the track pitch of about 0.68μm. With such setting, for example, even in case where reproduction is carried out by an optical system with a wavelength $\lambda$ of 405nm and an object lens having a numerical aperture NA of

0.65, the system information recording area is substantially free from interference from adjacent tracks and a stable track error signal is obtained.

[0049]

Recording encoding in the system information recording area may be same as or different from that in the data recording area. However, if it is troublesome to support two types of encoding on the side of the optical disc apparatus, the same encoding is preferably used.

[0050]

Furthermore, it is effective that the shortest pit length of the system information recording area is an approximate integral multiple of the shortest pit length of the data recording area. In this case, when an access is made over the two areas, a PLL for reproducing a signal clock can easily operate without substantially changing the rotation speed of the optical disc or altering the setting in a reproducing circuit. Of course, it is most effective that the system information recording area has the same linear recording density and the same track pitch in all of the reproducible-only type, the additionally recordable type, and the rewritable type. Accordingly, the shortest pit length may not be an exact integral multiple but may be a substantially approximate value. If a difference is 30% or less with respect to the integral multiple, the PLL circuit is sufficiently operable even with the same setting.

[0051]

Fig. 6 is a view showing one example of an optical disc apparatus according to an embodiment of this invention. As shown in Fig. 6, the optical disc 1 mounted on a spindle 6 is subjected to recording or reproducing of information by an optical head 7. Upon reproduction from the system information recording area, system information is reproduced by a binary equalizing circuit 12. By using the system information, setting of a PRML circuit 11 is carried out. On the other hand, upon reproduction from the data recording

area having a high recording density, partial response equalization is carried out by the PRML circuit 11 and data information is reproduced by Viterbi decoding.

[0052]

[Effect of the Invention]

As described above, according to the present invention, it is possible to provide an optical disc medium and an optical disc apparatus which are capable of realizing stable recording and reproducing by acquiring system information even if an optical disc has high-density recorded data.

[Brief Description of the Drawing]

[Fig. 1]

A view schematically showing a structure of an optical disc medium according to an embodiment of the present invention.

[Fig. 2]

A view showing an example of a characteristic of a data recording area in the optical disc illustrated in Fig. 1.

[Fig. 3]

A view showing a signal quality characteristic in partial response equalization.

[Fig. 4]

A view showing an example of a characteristic of a system information recording area in the optical disc illustrated in Fig. 1.

[Fig. 5]

A view showing an example of a characteristic of the system information recording area in the present invention.

[Fig. 6]

A view showing an example of an optical disc apparatus according to an embodiment of the present invention.

[Fig. 7]

A view for describing a signal reproduction characteristic.

[Fig. 8]

A view for describing a recording density characteristic.

[Fig. 9]

A view for describing partial response equalization.

[Description of Reference Numerals]

1 optical disc

2 data recording area

3 system information recording area

4 recording track

5 multi-value equalization level

6 spindle

7 optical head

11 PRML circuit

12 binary equalizing circuit

[Name of Document] ABSTRACT

[Abstract]

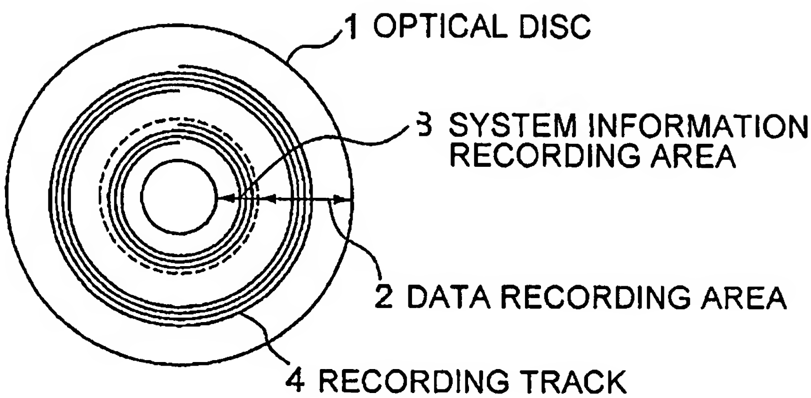
[Object] In an optical disc increased in density and using a PRML method for reproduction of a signal, to eliminate a disadvantage that stable reproduction of information is difficult when a PRML circuit is kept in an initial set condition.

[Means for Solution] Separate from a data recording area where high-density recording is carried out, a system information recording area is provided in which low-density recording is carried out and reproduction by binary equalization is easily carried out. Information required for circuit setting is recorded therein.

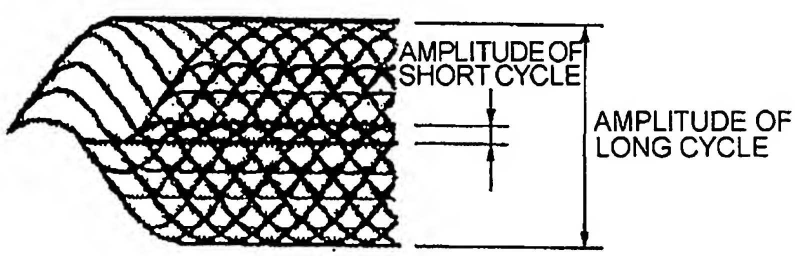
[Selected Figure] Fig. 1

[Name of Document] DRAWING

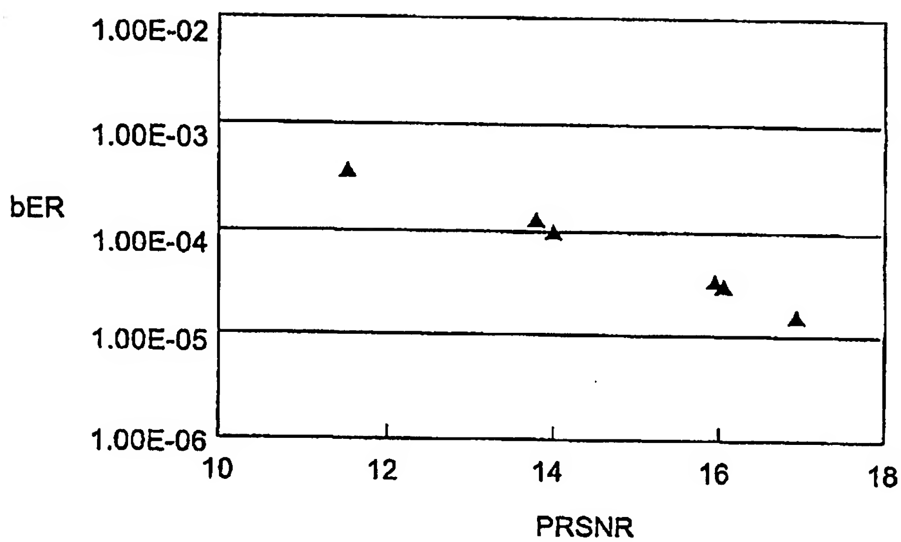
[Fig. 1]




[Fig. 2]

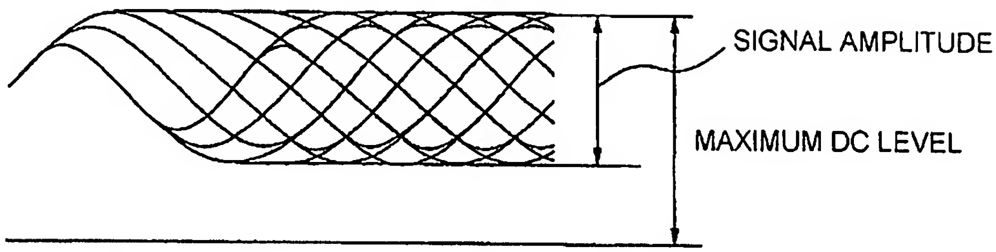


[Fig. 3]

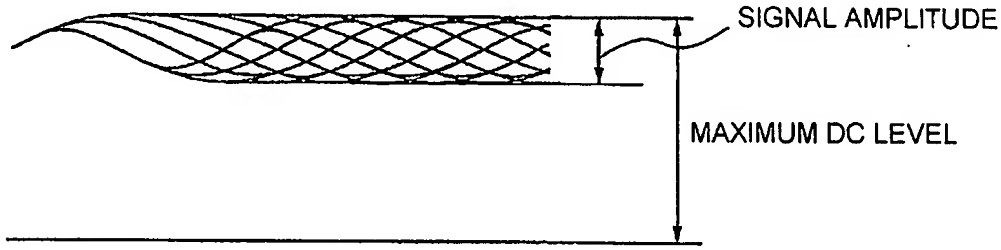


[Fig. 4]

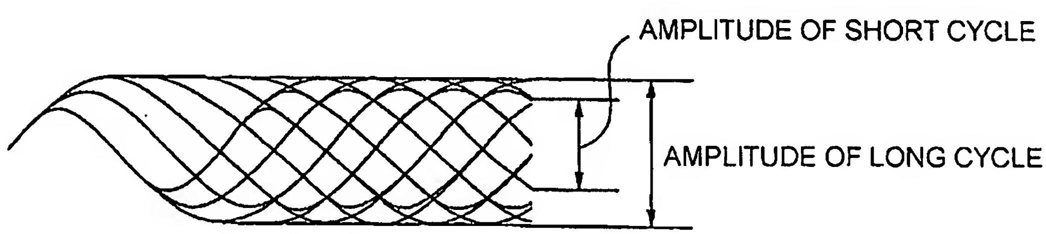
(a)


SIGNAL AMPLITUDE
MAXIMUM DC LEVEL

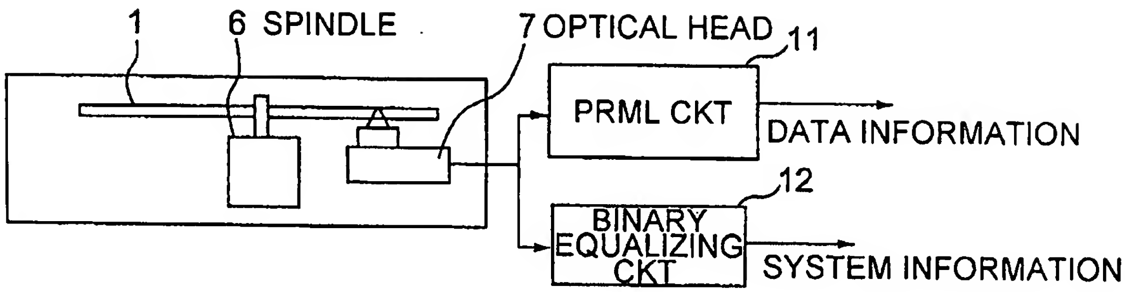
(b)


SIGNAL AMPLITUDE
MAXIMUM DC LEVEL

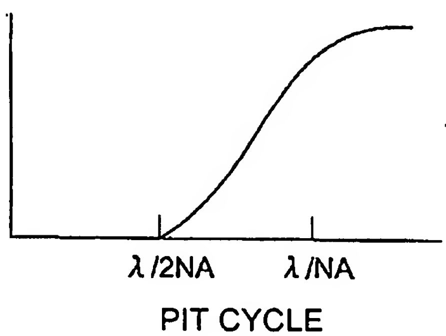
[Fig. 5]


AMPLITUDE OF SHORT CYCLE
AMPLITUDE OF LONG CYCLE

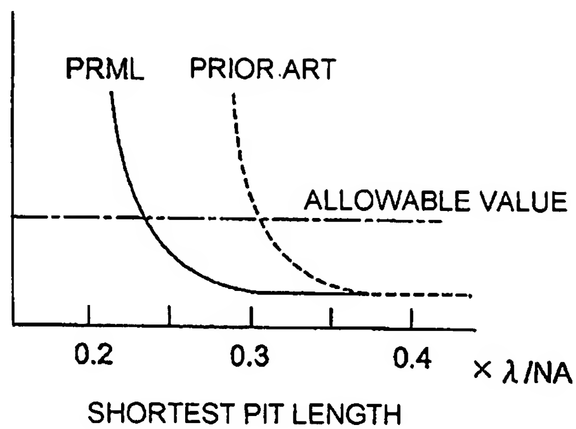
[Fig. 6]


1
6 SPINDLE
7 OPTICAL HEAD
11
PRML CKT
DATA INFORMATION
12
BINARY EQUALIZING CKT
SYSTEM INFORMATION

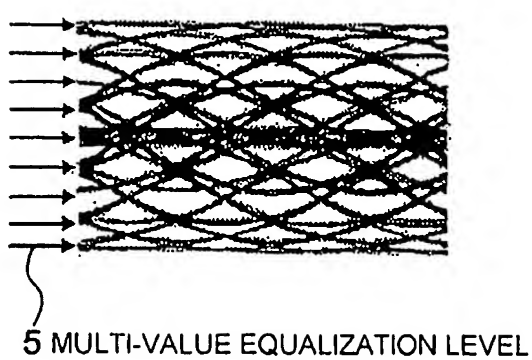
[Fig. 7]


λ/2NA
λ/NA
PIT CYCLE

[Fig. 8]


PRML
PRIOR ART
ALLOWABLE VALUE
0.2
0.3
0.4
× λ/NA
SHORTEST PIT LENGTH

[Fig. 9]


5 MULTI-VALUE EQUALIZATION LEVEL